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Influence of the Leeuwin Current on the distribution of fishes and the composition of fish assemblages

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Abstract

Change in the structure of fish assemblages was examined across the 100 km north-south stretch of the Houtman Abrolhos Islands, Western Australia and related to the southward flowing warm Leeuwin Current. Assemblages to the north at Ningaloo Reef and to the south at Rottnest Island were also compared to Houtman Abrolhos assemblages with reference to the Leeuwin current. Fish data was collected at all locations using baited remote underwater stereo-video systems (stereo-BRUVS) in depths of 8–12 m. 105 fish species were surveyed at the Houtman Abrolhos Islands during this study, 21% of these species have a warm-temperate latitudinal distribution, 13% sub-tropical and 66% tropical. Fish assemblages surveyed at the Houtman Abrolhos were distinct from, and somewhat intermediate between, fish assemblages surveyed to the south at Rottnest Island and to the north at Ningaloo. The composition of fish assemblages differed greatly across the four island groups of the Houtman Abrolhos and between sites within each group. While the Houtman Abrolhos fish assemblage is strongly influenced by the Leeuwin current, large small-scale variability in assemblages within and across island groups is likely driven by non-exclusive factors such as the patchiness or complexity of the habitat, predator/prey relationships and competition.

Introduction

Located on the edge of the continental shelf between 28°15'S and 29°S the Houtman Abrolhos is directly influenced by Western Australia's dominant ocean current – the Leeuwin Current (Pearce 1997). The Leeuwin Current flows southward along the West Australian coast bringing warm water from the tropics. Passing directly through the Houtman Abrolhos the current facilitates the existence of the most southern true coral reefs of the Indian Ocean (Veron & Marsh 1988) and a marine ecosystem comprising a high proportion of tropical species (Maxwell & Cresswell 1981; Morgan & Wells 1991; Huisman 1997).

Previous research on fish assemblages of the Houtman Abrolhos includes qualitative taxonomic surveys of fish assemblages (Hutchins 1994; Hutchins 1997a, b; Hutchins 2001), species-specific demographic research (Nardi *et al.* 2006) and assessments of the effects of fishing on reef fish species (Nardi *et al.* 2004; Watson *et al.* 2007). Fish fauna of the Houtman Abrolhos currently totals 389 species, 66% of which are tropical, 19% warm-temperate and 13% sub-tropical (Hutchins 1997a). The majority of tropical species at the islands are in low abundance suggesting that the Houtman Abrolhos relies heavily on the south-ward flowing Leeuwin Current to deliver tropical recruits (Hutchins 1994, 1997b). The Houtman Abrolhos may also be a source of tropical recruits for Rottnest Island some 400 km to the south via the Leeuwin Current (Hutchins 1997b). Not all tropical fish species at the Houtman Abrolhos necessarily rely on the Leeuwin Current for the maintenance of breeding populations. For example, the common and abundant coral trout (*Plectropomus leopardus*), has been shown to be genetically distinct from populations to the north (van Herwerden *et al.* 2006) and therefore appears to be maintaining breeding populations at the Houtman Abrolhos Islands.

The temperate-tropical convergence location of the islands permits co-existence of warm-temperate, sub-tropical and tropical fish species that distinguish the Houtman Abrolhos from adjacent mainland and areas further to the north and south (Hutchins 1994). Less clear is the change in composition of fish assemblages across the latitudinal gradient of the islands themselves which span 100 km from the North Island to the southern Pelsaert group. Here we examine the structure of fish assemblages across the four island groups of the Houtman Abrolhos and discuss differences between the islands assemblages to those studied to the south at Rottnest Island and to the north at Ningaloo using the same sampling technique.

Materials and Methods

Sampling Design

Surveys were conducted from May 17th–22nd, 2007 at the four island groups of the Houtman Abrolhos; Pelsaert, Easter, Wallabi and North (Figure 1). At each

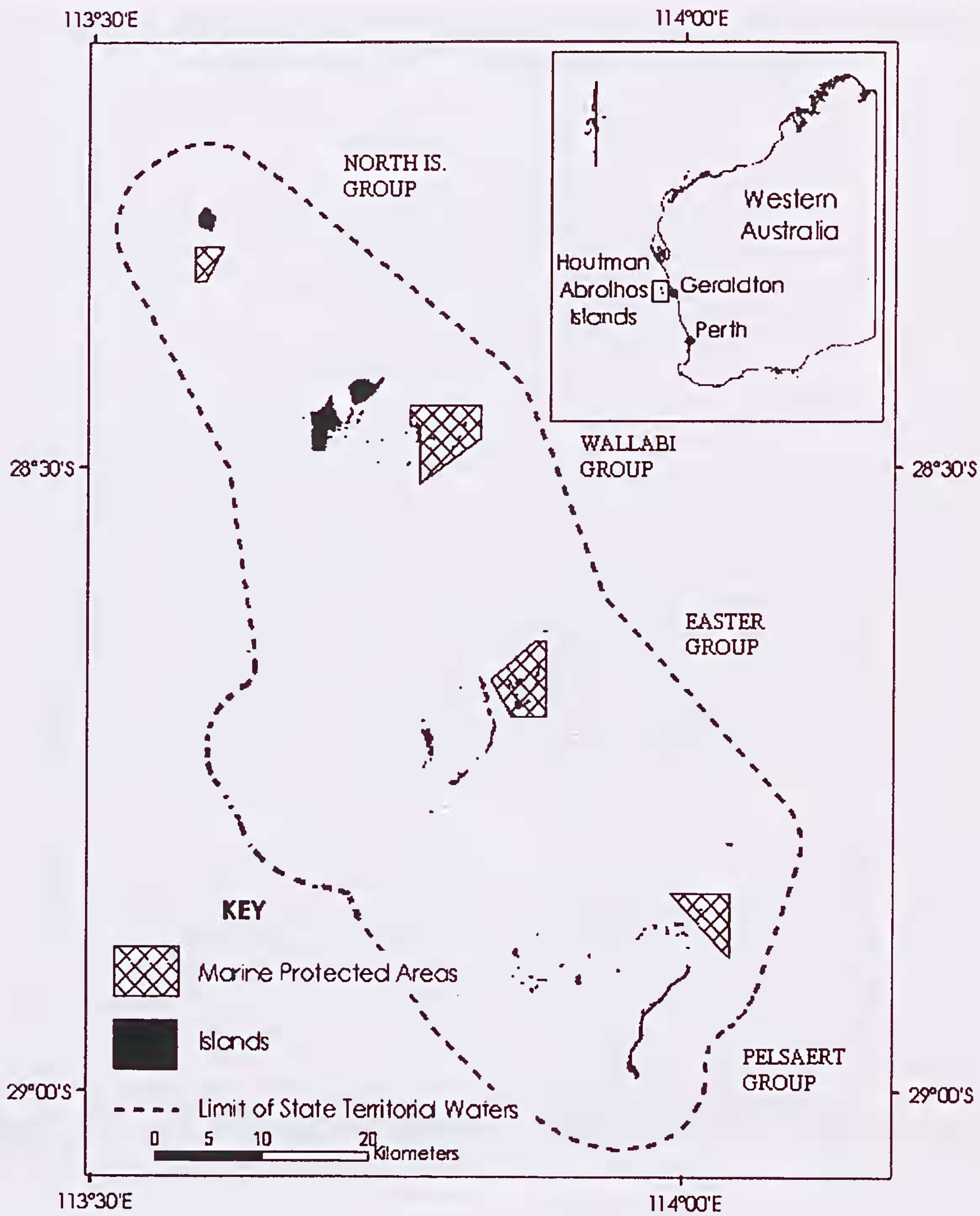

Figure 1. Map of the Houtman Abrolhos Islands.

island group, fish were surveyed on shallow reef slopes (8–12 m depth) at three randomly located areas separated from each other by hundreds to thousands of metres. All locations were of similar high exposure, bordering deep channels or on the edge of large islands exposed to the open ocean. Sampling was standardised by habitat with all surveys conducted along reef slopes where habitat was predominantly branching and plate *Acropora* spp. Five replicate samples were collected at each of the three locations for each island group.

Fish assemblages at Rottnest Island and at Ningaloo have also been surveyed using the same technique at similar depths. Therefore, we were able to compare fish assemblage composition at the Abrolhos to the composition of assemblages 750 km to the north at Ningaloo (latitude 22°) (B Fitzpatrick & E Harvey unpubl. data) and 400 km to the south at Rottnest Island (latitude 32°) (WA Marine Futures unpubl. data). Note that sampling effort was not equal between the locations with only 19 sites from Rottnest and 11 sites from Ningaloo included in comparisons to the Abrolhos (60 sites).

Sampling technique

Baited remote underwater stereo-video systems (stereo-BRUVS) were used to survey fish assemblages

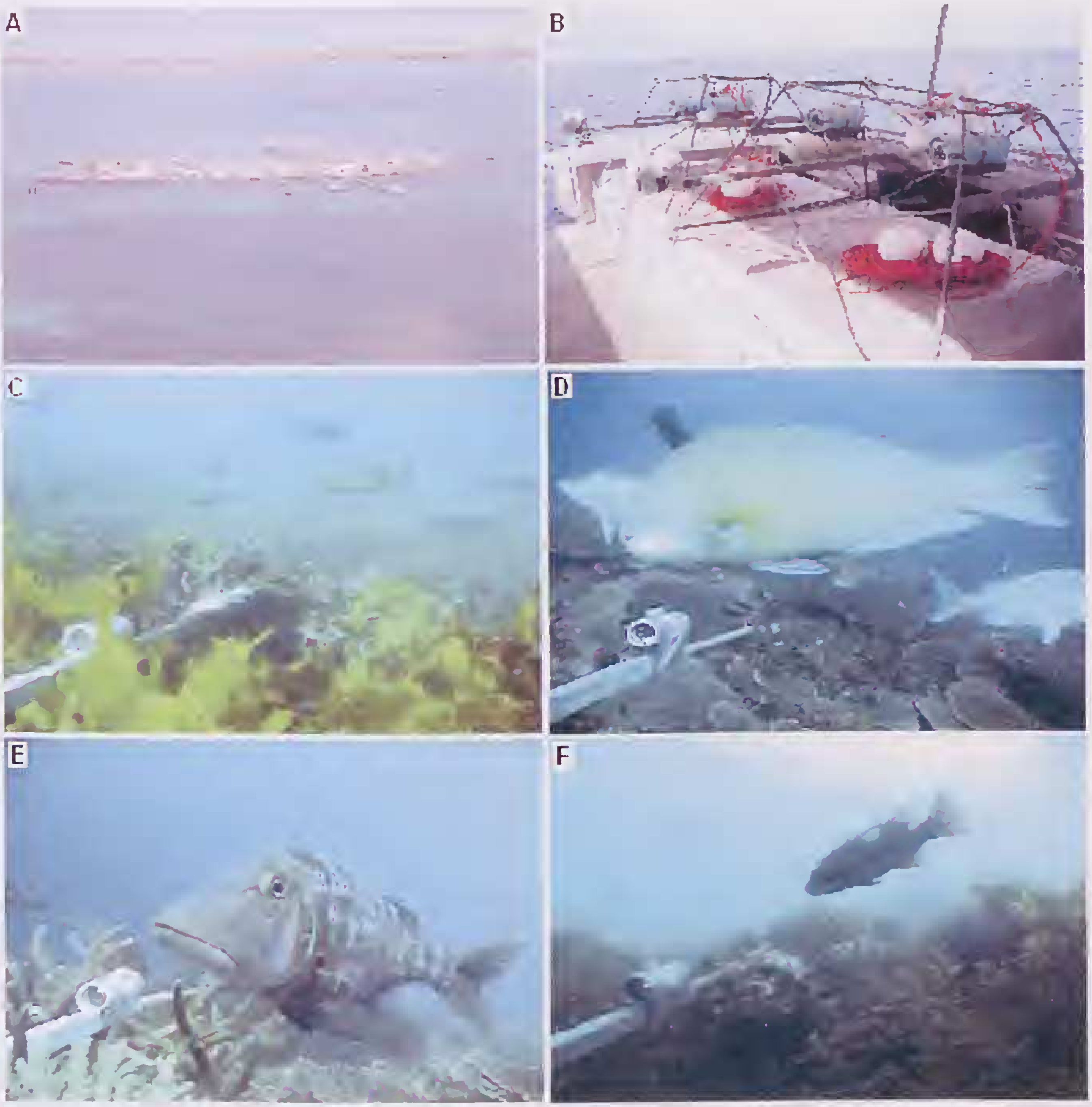

Figure 2. Selection of images from the Houtman Abrolhos Islands. A) A typical inhabited island with rock lobster fishers camps; B) stereo-BRUV camera setup; C) the tropical coral trout, *Plectropomus leopardus* amongst staghorn coral and kelp; D) the sub-tropical baldchin groper, *Choerodon rubescens;* E) the tropical redthroat emperor, *Lethrinus miniatus;* F) the temperate western foxfish, *Bodianus frenchii.*

(Figure 2B). Detailed information on their design, use and measurement accuracy can be found in the literature (Harvey & Shortis 1996; Harvey *et al.* 2001a, b, 2002, 2004). Simply, the stereo-BRUV systems are comprised of two SONY HC 15E video cameras in water-proof housings, mounted 0.7 m apart on a base bar inwardly converged at 8 degrees to gain an overlapping field of view (Harvey & Shortis 1996). Research has shown that in addition to species expected to visit baited stations, stereo-BRUVs also survey prey and herbivorous species, some cryptic crevice dwelling species (*e.g.*, Muraenidae, Pseudochromidae spp.) and transient species (*e.g.*, Scombridae) (Watson *et al.* 2005, 2007; Harvey *et al.* 2007). Other advantages of the technique relevant to this study include; storage of footage for fish identification, safety in the field (no SCUBA) and rapid field sampling (Watson *et al.* 2007). The present study used 8 stereo-BRUV systems such that each could be deployed by boat, one after the other, at separate sites. After one hour (max tape recording time) the first would be retrieved and re-deployed then the second retrieved, re-deployed, and so on, facilitating high sampling efficiency. The bait consisted of 800 grams of pilchards (*Sardinops sagax)* in a plastic-coated wire mesh basket that was suspended in front of the two cameras. The pilchards were crushed to maximise bait dispersal. Adjacent replicate deployments were separated by 250–400 m to ensure similar coral cover while reducing the likelihood of fish moving between each stereo-BRUV within the sampling period. Temperate loggers (TidbiT v2) were attached to each of the eight stereo-BRUV frames to obtain *in situ* measures of temperature. The loggers were set to record temperature every 10 minutes providing 6 measures for each deployment.

In the laboratory, video images of each site were reviewed and all fish observed were identified to species and catalogued using the software program EventMeasure (SeaGIS 2008). EventMeaure, in addition to other measures, permits the relative abundance of every species to be logged. These relative abundance counts are known as 'MaxN', *i.e.*, the maximum number of fish belonging to each species, present in the field of view of the cameras at one time (see also Priede *et al.* 1994; Willis & Babcock 2000; Cappo *et al.* 2004). By using MaxN we avoid repeatedly sampling a single individual. It is often the case that only a portion of fish will be visible at one time and therefore MaxN is a conservative estimate of the number of fish in the vicinity of the cameras.

The percent cover of different habitat types was estimated from freeze-framed video images for every site. This measurement was made by visually estimating what percent of the total field of view of the substrate each habitat type occupied. Seven common and broad habitat types were often observed on video images. These habitat types included; staghorn coral (branching *Acropora* spp.), plate coral (plate *Acropora* spp.), other coral species, kelp (*Ecklonia radiata;* Figure 2C), other algae (usually *Sargassum* spp.), sand and coral rubble.

Statistical Analyses

The experimental design consisted of two factors: island group (four levels, fixed: Pelsaert, Easter, Wallabi and North) and site (nested in island group, random with three levels). One hundred and five fish species were included in the multivariate analyses. The multivariate data set was analysed using permutational multivariate analysis of variance (PERMANOVA) (Anderson 2001) in the Primer-E software package. This permutational distance-based approach was used for analyses because the relative abundances of fish were highly skewed and contained many zero counts. All multivariate analyses were conducted using the Modified Gower log base 10 dissimilarity matrix on raw untransformed relative abundance data. Analysis of percent cover of habitat types was conducted in a similar manner but instead using Euclidean distance on arcsine transformed percentages. Furthermore, the habitat types (arcsine percentages) were included as covariables in the PERMANOVA analysis on relative abundance data. The contribution of habitat and temperature to variation in fish assemblages was examined using DISTLM (distance-based multivariate analysis for a linear model; McArdle & Anderson 2001). A canonical analysis of principal coordinates (CAP; Anderson & Robinson 2003; Anderson & Willis 2003) was also conducted on relative abundance data to examine whether fish assemblages could be discriminated across the four island groups. Individual species likely to be responsible for any observed differences between island groups were determined by examining Pearson correlations of species counts with canonical axes. A correlation of $|r| > 0.3$ was used as an arbitrary cut-off to display potential relationships between individual species and the canonical axes. Fish assemblages from Ningaloo and Rottnest Island were compared to the fish assemblage at the Abrolhos Islands using the PERMANOVA procedure described above with a single factor; location.

Results

Rottnest Island, Ningaloo and the Houtman Abrolhos each have distinctly different fish assemblages (Figure 3; $p < 0.01$, allocation success 100%). Of the 105 fish species surveyed at the Abrolhos, 21% have a warm-temperate latitudinal distribution, 13% sub-tropical and 66% tropical. At Rottnest Islands 91% of the fish species surveyed (53 species) have a warm-temperate distribution, 7% sub-tropical and 2% tropical. Of the 83 species surveyed at Ningaloo, none had a warm-temperate distribution, 8% were sub-tropical and 92% tropical. 23 species were common to Rottnest Island and the Houtman Abrolhos and 37 species were common to the Abrolhos and Ningaloo. Only a single species was recorded at all three locations, the moon wrasse *Thalassoma lunare*.

Stereo-BRUV surveys of fish assemblages across the four island groups of the Houtman Abrolhos recorded 5645 individuals from 105 species and 32 families with 14 species being endemic to Western Australia (13.3%). The ten most common fish species observed on stereo-BRUV images include; *Plectropomus leopardus* (Figure 2C), *Choerodon rubescens* (Figure 2D), *Pomacentrus milleri, Scarus schlegeli, Coris auricularis, Thalassoma lutescens, Thalassoma lunare, Lethrinus miniatus* (Figure 2E), *Labracinus lineatus* and *Pagrus auratus.*

From stereo-BRUV images the 7 habitat categories varied greatly at the smallest level of sampling (Site; d.f. = 8,59; MF = 5957.4; Pseudo F = 2.29; $p = 0.001$). Similarly, water temperature also varied at the site level (d.f. = 8,59; MF = 1.19; Pseudo F = 3.13; $p = 0.006$). Neither habitat or temperature differed significantly across the four island groups (all $p > 0.05$). Of the 7 habitat categories, 4 had a significant effect on the variation in fish assemblages; branching *Acropora* spp., plate *Acropora* spp., other coral species and sand (all $p < 0.04$). Together, habitat and temperature accounted for 21.6% of the variation in the relative abundance of fishes. On its own temperature only accounted for 1%. The inclusion of habitat as a covariable in the PERMANOVA analysis showed that habitat, although highly variable across sites, did not contribute to differences in fish assemblages across any levels of the model (non-significant interaction values; Table 1). Relative abundances of all fish species and families differed significantly across the four island groups (Table 1). Pairwise comparisons could not identify which island groups were driving this significant group effect (all $t < 2.3$; $p > 0.05$). PERMANOVA on latitudinal groups (species summed to warm-temperate, sub-

Table 1

PERMANOVA based on Modified Gower log base 10 dissimilarities of relative abundances of 105 fish species in response to habitat covariables (CO), island group (Gr), sites (Si) and their interactions.

Source	df	105 species variables			32 Family variables		
		MS	Pseudo-F	P(perm)	MS	Pseudo-F	P(perm)
CO	7	1.01	1.86	0.06	1.14	2.54	0.02
Gr	3	1.01	1.49	0.05	1.02	1.77	0.05
Si(Gr)	8	0.68	1.41	0.16	0.58	1.46	0.19
COxGr	15	0.49	1.02	0.49	0.41	1.03	0.48
COxSi(Gr)	14	0.43	0.90	0.69	0.42	1.07	0.42
Res	12	0.48			0.39		
Total	59						

tropical or tropical) found no significant differences across island groups ($p = 0.75$).

Similar to PERMANOVA, a CAP analysis on species data showed fish assemblages differed across the four island groups ($p = 0.002$; Figure 4). Canonical axes separated fish assemblages present at each of the island groups well, with no overlap. This distinctiveness of the assemblages at each island group was illustrated by leave-one-out allocation success rates from the CAP analyses that were >67% (Table 2). When species were summed to families and to latitudinal groups, CAP also found a difference between island groups (both $p < 0.01$). At the family level, allocation success rates were low with 46% for the Wallabi group, 60% for the Easter and North group and 66% for the Pelsaert. For latitudinal groups, allocation success rates were lower still with only 6% of sites correctly assigned to the Wallabi group, 40% to North Is, 53% to the Easter group and 60% to the Pelsaert group. Therefore, at the family and latitudinal group level, assemblages showed greater overlap across island groups particularly at the two northern groups.

17 species were identified by CAP as having a strong Pearson's correlation with canonical axes that separated island groups. Associated with the North Island were; *Apogon angustatus*, *Chromis westaustralis*, *Lethrinus atkinsoni*, *Lethrinus nebulosus* and *Lethrinus sp*. Associated with the Wallabi group were; *Coris auricularis*, *Lethrinus miniatus*, *Scarus ghobban* and *Thalassoma lunare*. Fish species associated with the Easter group included; *Bodianus frenchii*, *Chaetodon assarius*, *Chaetodon lunula*, *Chlorurus sordidus*, *Dascyllus trimaculatus* and *Labracinus lineatus*. Finally, species associated with the Pelsaert group were *Gymnothorax woodwardi* and *Scorpis*

Table 2

Allocation success of replicates to island groups (# correct out of 15) for fish data. Note that with four groups a 25% success rate would be expected if results were no better than random.

Island Group	# correct	Allocation success (%)
Pelsaert	11/15	73
Easter	10/15	67
Wallabi	11/15	73
North	13/15	87

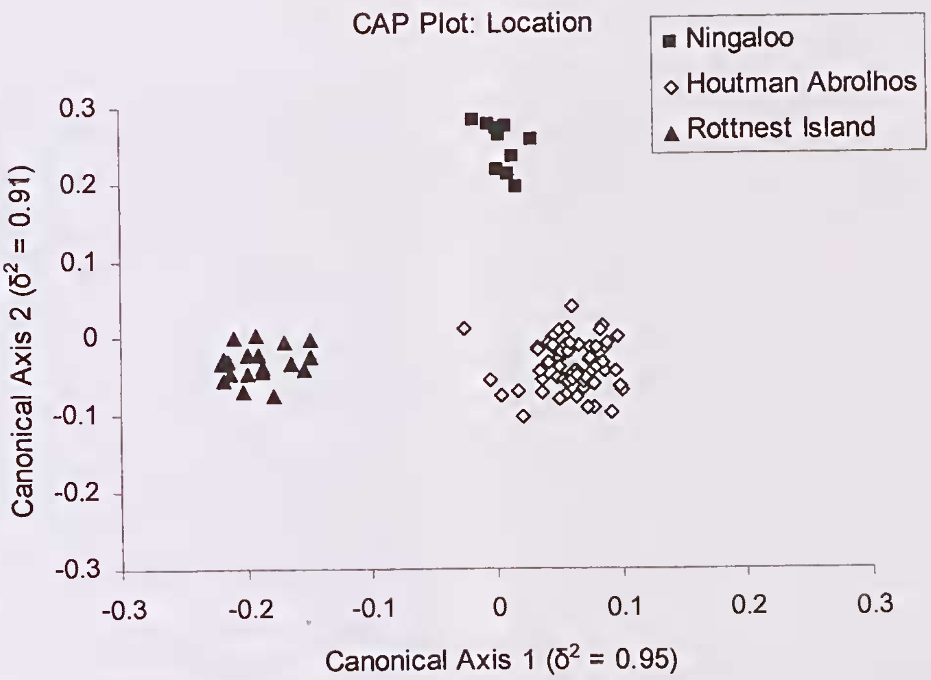

Figure 3. Canonical analysis of principal coordinates (CAP) ordination for locations.

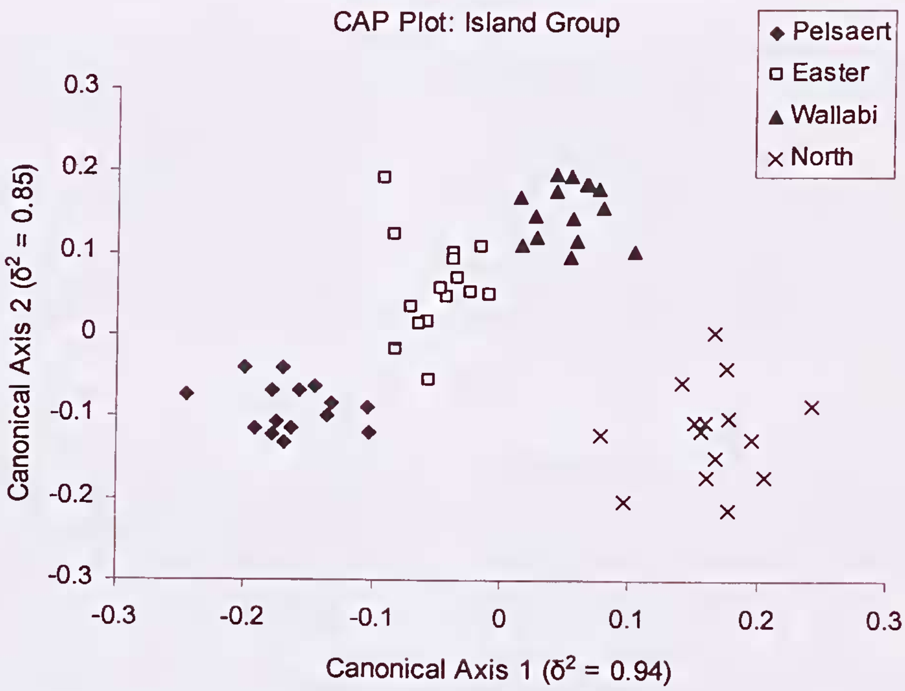

Figure 4. Canonical analysis of principal coordinates (CAP) ordination for island group.

georgianus. Many of the most common and abundant species viewed on video images were present at all island groups, *e.g.*, *Plectropomus leopardus*, *Pomacentrus milleri*, *Choerodon rubescens*, *Pagrus auratus*, *Thalassoma lutescens* and *Scarus schlegeli*. Because the distinction between island groups was not as pronounced at the family level, only several families of fish exhibited correlations to particular island groups. The families Muraenidae and Serranidae were associated with the Pelsaert group while Scaridae and Chaetodontidae were associated with the Easter group.

Discussion

The Leeuwin current is thought to strongly influence the structure of fish assemblages with many fish species likely relying on recruitment from more northern populations via the southward flowing current (Hutchins 1997b). While fish assemblages at the Houtman Abrolhos comprise mostly tropical fish species, numbers of tropical species are low compared to assemblages further to the north around Ningaloo (see also Hutchins 1994). This impoverished tropical diversity is reflective of the temperate-tropical overlap location of the Houtman Abrolhos. Compared to Rottnest Island which is 400 km to the south, the Houtman Abrolhos have a much higher proportion of sub-tropical and tropical fish species. Tropical fish species at Rottnest may have travelled there via the Leeuwin Current from the Abrolhos Islands (Hutchins & Pearce 1994).

Hutchins (1997a) recorded 389 fish species across the Pelsaert, Easter and Wallabi groups, significantly more that what was recorded here (105 species) from the four island groups. The difference is most likely a result of sampling effort and techniques where Hutchins (1997a) used a combination of observational (underwater visual census) and destructive (spearing, trawls, handnets and rotenone) techniques. Despite the comparatively low number of fish species recorded using stereo-BRUVs, a number of species were observed for the first time at the islands; *Naso brevirostris*, *Pterocaesio digramma*, *Hemigymnus fasciatus* and *Pentapodus nagasakiensis*. These species are all tropical and may have recruited to the islands in 2000 when the Leeuwin Current was particularly strong (B Hutchins *pers comm*.). With greater sampling effort at the islands using a range of techniques we predict that a large number of species will be reported for the first time. Our findings support those of Hutchins (1997a) in suggesting that any change to the south-ward flowing Leeuwin Current would have an enormous impact on fish assemblages at the Abrolhos Islands.

Given the temperate-tropical transitional location of the islands and the southward flowing warm Leeuwin Current, one would expect a gradual decline in the number of tropical fish species from the North Is. to the Pelsaert group some 80–100 km to the south. Indeed a number of tropical fish species did exhibit this trend (*Lethrinus miniatus* (Figure 2E), *Lethrinus nebulosus*, *Lethrinus sp* and *Thalassoma lunare* associated with the North Is.*)*. Furthermore, a number of temperate species were highly associated with the more southern island groups (*Scorpis georgianus*, *Gymnothorax woodwardi*, *Bodianus frenchii*; Figure 2F). For the majority of fish species, however, their distribution did not appear to be related to latitudinal location. Our data suggest that while the Leeuwin Current strongly impacts the composition of fish assemblages at the Abrolhos, the southward flowing current does not appear to strongly influence the distribution of fish species across the four island groups. Seasonal and more extensive studies, however, would need to be conducted to further examine this.

High variability in fish assemblage structure at the smallest scale of sampling (between sites) could be a caused by a number of factors including; food availability, competition, exposure, available habitat, predator/prey relationships and fishing pressure. Furthermore, the presence of fish species in particular areas may also vary with age and ontogeny (Forrester 1991; Clements & Choat 1993; McCormick 1998; St John 1999). Several habitats did have a significant influence on variability in fish assemblages (categories: branching *Acropora* spp, plate *Acropora* spp, other macroalgae and sand). This influence, however, was not sufficient to explain observed differences in assemblages across sites or island groups. Habitat and temperature, while also highly variable at relatively small spatial scales, explained 21% of the variability in fish assemblages. Examination of habitat from video images is very restrictive however, and measures rely strongly on the orientation of the cameras. Links between habitat types observed on video footage and fish assemblages in the area would likely have been stronger if bait was not used. By using bait we are attracting mobile fish species into the field of view of the cameras and for some species they may be drawn away from their preferred habitat. Benthic habitat surveys which characterise habitat presence, extent and rugosity, in combination with fish surveys (stereo-BRUVS and underwater visual census techniques) would provide a much better insight into fish-habitat relationships at the Houtman Abrolhos Islands.

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